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CONDITION AND TREND STUDY:
FINAL TECHNICAL REPORT.

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FINAL TECHNICAL REPORT ON THE CONDITION AND TREND STUDY

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FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

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INTRODUCTION

The range condition and trend study was conducted within the western national forests by the Division of Range Research of the Washington office with the cooperation of the Division of Range Management and the six western regions and experiment stations. Since its inception in July 1948, study plans and findings have been periodically reported (___, ___, ___). In brief, the primary objective of the study was to develop a method or methods which is simple, practical, accurate, technically sound, and which would yield concrete measurements as well as sound observational evidence of trend.

The study culminated in the processed release entitled "A Method for Measuring Trend in Range Condition on National Forest Ranges" issued October 17, 1951. This release has been given wide distribution throughout the Forest Service, to livestockmen and State livestock associations, to other federal agencies interested in range lands, to State agricultural colleges and experiment stations, and State game departments. This release covered in detail the specifications of the three-step method. It did not, however, summarize the various technical findings of the various tests that were made of the method as to sensitivity and reliability during the 1950 field season. It is the purpose of this paper to summarize pertinent previous work, and to report additional findings as a technical supplement and as the final step in the completion of the condition and trend study.

SENSITIVITY AND RELIABILITY OF THE THREE-STEP METHOD

STEP ONE - THE LOOP METHOD

Major consideration of the sensitivity and reliability of the Three-Step Method most logically centers around Step One by which the initial site data are collected. Previously made tests on Step one have been reported (___). Therein are included information on the: Origin of the "loop" or "ring" method; how the data on density index and composition compared with that obtained by other methods; where and how it was tested; the magnitude of differences arising from line replacement and between different men making the measurements; and sensitivity of the method in recording change.

The advantages of the loop method were reported as follows:

> Results of the 1949 field tests indicate the loop method to have much promise as an administrative tool for securing information on trends in range vegetation. It is simple, readily understood, and men can be easily trained in its use. It provides reasonably accurate indices of: density of vegetation, floristic composition, amount of litter as it occurs between plants, bare soil, and exposed rock. Equipment required is extremely simple. The measurements may be obtained by one man within a reasonable period of time. Data obtained are readily interpreted and are subject to statistical analysis if that appears desirable at any time. Differences between men (as well as differences resulting from line replacement) in many of the 1949 trials were not significant and, where they did occur, were not prohibitive. Additional testing for uniformity between men is probably not necessary. Sensitivity of the method in reflecting wide changes as from one range condition class to another is adequate. Likewise, the method appears to be reasonably sensitive for detecting smaller changes within a condition class, although this would justify some further testing. Accordingly, the method is believed to be technically sound and that it will be met with acceptance and approval of range ecologists.

The limitations of the loop method were pointed out as follows:

> The loop method has certain limitations which should be recognized. These limitations may be segregated into two groups: those which can only be overcome or reduced by adoption of proper precautionary measures and

those which may be corrected for by further refinement of the method.

First of all, the loop method is not a method to be applied without instruction. Careful and thorough field training of personnel must be carried out prior to actual application. The sample obtained is so small that, in order to determine trend, the utmost care and precision must be observed in obtaining the initial and subsequent measurements. Like any other method, plants with unusual growth forms will have to be specifically defined and the definitions carefully adhered to in order to achieve the greatest uniformity between men. Personnel gathering the data must be able to identify or recognize the more important range plant species. If rangers collect the data, they may need assistance and guidance in its analysis and interpretation.

Features of the loop method which should be further investigated in order to achieve necessary refinement include:

1. Additional testing on the sensitivity of the loop method for reflecting minor changes in vegetation. To carry out this evaluation on the magnitude of changes that may be detected will require assembly of certain information. This would be with respect to the magnitude of changes and the rate with which they may occur in the more important range types, as determined by other methods.

2. Loop method readings do not express forage or herbage production. The only indication of this would be in the appraisal of vigor as called for in Step Two and the reflection of the loop index of density and plant composition on forage production. Information on the trend in herbage or forage production would be of great value.

3. Additional testing is needed in several other important range types not encountered in 1949, including aspen, mountain brush, and the high mountain grassland of the Intermountain region.

4. The index of litter cover tells nothing as to its volume or depth. Information on the latter might be obtained by recording the litter readings in depth classes.

5. The present size (3/4" diameter) of the loop appears adequate for most situations. However, it is possible in special cases that loops of two sizes might be used, including the present size in combination with a larger one to pick up rare but important indicator species. The use of different size plots or "double

sampling" is standard practice in the Forest Survey for recording tree seedlings, pole size reproduction, and volume of timber.

6. The present length of transect line is 100 feet. It is not known whether this is the most efficient length of line for sampling. It is possible, too, that lines of shorter length would afford greater accuracy in making the measurements.

7. The possibilities of improvement of equipment in order to secure greater uniformity between men should be followed up. As, for example, improvement of the plumbing quality of the loop and finding a better means for stretching the tape.

8. Exact specifications for staking out transect lines, witness stakes, metal tags for marking the sampling areas, close-up frames for photo-plots, simplified forms for recording all data, etc., should be worked out.

Results of the tests conducted in 1950 and subsequently are presented in the following subsections which are numbered to correspond with the above list of problems related to the loop method. Items 7 and 8 are omitted because desirable improvements and modifications are now incorporated within the present specifications of the three-step method (___).

1. Results of Tests on Sensitivity of Step One

The requirement that the method be sensitive in reflecting changes in condition is of equal or greater importance than securing uniformity between men, because personal error between men can be reduced by increasing the number of plots or clusters. Obviously, it was not possible during the development of the method to wait a year or more for known changes (i. e., as arising from drought) to take place on the transect lines established in the several regions in connection with the study. Accordingly, various means were employed to simulate change or compare condition situations representative of known changes.

Summary of previous work.--As previously reported, it is possible on the basis of the same data (collected primarily to determine uniformity between men), to examine this material from the viewpoint of sensitivity of the method. Whenever possible to do so, sampling sites within a range type were deliberately placed in different condition situations. The results of these analyses are presented in table 1. It will be noted that the magnitude of actual difference that would have to occur before it could be detected with confidence by the loop method is comparatively small in most instances. When placed on the basis of percentage change required, the range is greater, these tests indicating a range from 6 to 42 percent.

Although the data utilized in these calculations are for various site factors such as the desirable or climax grass species, browse, and litter, it is believed that similar relationships would obtain with the intermediate species and with rock, moss, and other site factors. For example, the item of "desirable grasses" in the three condition situations found in the Pacific bunchgrass type of Oregon would obtain just as well with the intermediate grasses such as Sandberg bluegrass. This is borne out by the data for intermediate grasses (mostly blue grama) in Colorado. This is important because the climax species might be entirely lacking on a range in very poor condition and change in the intermediate species would have to be relied upon as a measurement of trend.

It will be noted further in the case of litter determinations (California data) that the magnitude of difference required compares favorably with the other elements. This is important because litter (as with bare soil, rock, and pavement) is in the nature of a subjective estimate (±50%) of the amount within the loop, whereas perennial

Table 1.--Magnitude of differences for several site factors that can be detected by the loop method with confidence at odds of 19 to 1

Location and range type	Site factor	Average loop index of density	Magnitude of difference required (±)	Percent change required (±)	Number of lines required
Oregon	Desirable grasses				
Pacific bunch-	Fair condition	37.95	9.5	25	12
	Hi-poor condition	10.10	2.8	28	22
	Poor condition	3.05	1.3	42	3
Colorado					
Ponderosa pine-	Intermediate grass				
bunchgrass	Good condition	29.2	6.0	20	5
	Fair condition	34.8	2.0	6	8
	Poor condition	35.2	3.0	8	6
California					
Mountain shrub-	Browse	32.3	2.0	6	12
incl. sagebrush-	Litter	28.3	5.0	18	22
grass					
Montana					
Mountain grass-	Total grasses	41.4	3.5	8	22
land					
Wyoming					
Sagebrush-grass	Browse	27.4	2.0	7	5
	Total grasses	14.2	2.0	14	7
Arizona					
Shortgrass-	Total grasses	27.4	4.0	15	6
woodland					

vegetation is more of an objective measurement. In the case of perennial vegetation, the examiner makes only the simple decision of--it is or isn't within the loop.

These analyses indicate the loop method to be reasonably sensitive in picking up changes in vegetation and other factors. In order to pick up changes within a condition class the sensitivity will depend on the limits that are set for that particular condition class as defined in the standards set up for the type. For example, in the Pacific bunchgrass type differences within the poor condition class are readily picked up with respect to desirable species. It would not be so sensitive enough to pick up reliably species which occur as a mere trace except by measuring a prohibitive number of transect lines. It is for this reason that important key indicator species of the three plant groups be reported whenever they occur but are not recorded in measurement of the transect line.

Results of 1950 Tests.--As an additional check on the sensitivity of the loop method tests were conducted in the subalpine grassland type of the Manti National Forest, Utah, in 1950. Deterioration in this community is often characterized by marked increase of sweetsage (Artemisia discolor). This rhizomatous plant is single stemmed in its aerial growth. Each stem is distinct, about 1/8 inch in diameter, and grows unevenly spaced from the rhizomes. They are easily counted. The study plan required the establishment of 12 belt transects within patches of the sweetsage. Each transect was 4 inches wide and 25 feet long and 100 loop observations were made in the center of this belt as to crown and basal occurrence of sweetsage. Then the belt transect was divided into six segments and about 20

percent by actual count of the sweetsage plants were cut and removed at random within the belt. The transect was then remeasured by the loop method. The same procedure was followed in further removal of sweetsage at about 20 percent steps up to and including 80 percent removal.

The average percentages for the 12 transects are presented in table 2. It will be noted that the percentage removal determined from the average basal index of density on the 12 transect lines is very close to that shown by actual count of sweetsage plants. Percentage removal as indicated by the index of crown density is not quite so good but is still fairly close to the actual.

Averages can be misleading as to the accuracy with which a method measures change. However, such was not the case in the sweetsage removal tests. Further analysis of the field data was made by simple regression analyses with additional determination of the confidence limits. Results are shown graphically in figures 1 and 2. Percentage sweetsage removal as determined from either the basal or the crown index of density is very close to actual. The graph line for this is closely paralleled by the 5 percent confidence bands, and the relationship is nearly linear so that the error for large or small values is not much greater than for intermediate values. This also means that the chances are only 1 in 20 that the mean of a similarly obtained sample (in this case 12 transects) or of a single transect will occur beyond the limits indicated by the confidence bands--either above or below them.

Considering these tests, together with the information on sensitivity presented in table 1, the loop method appears to be

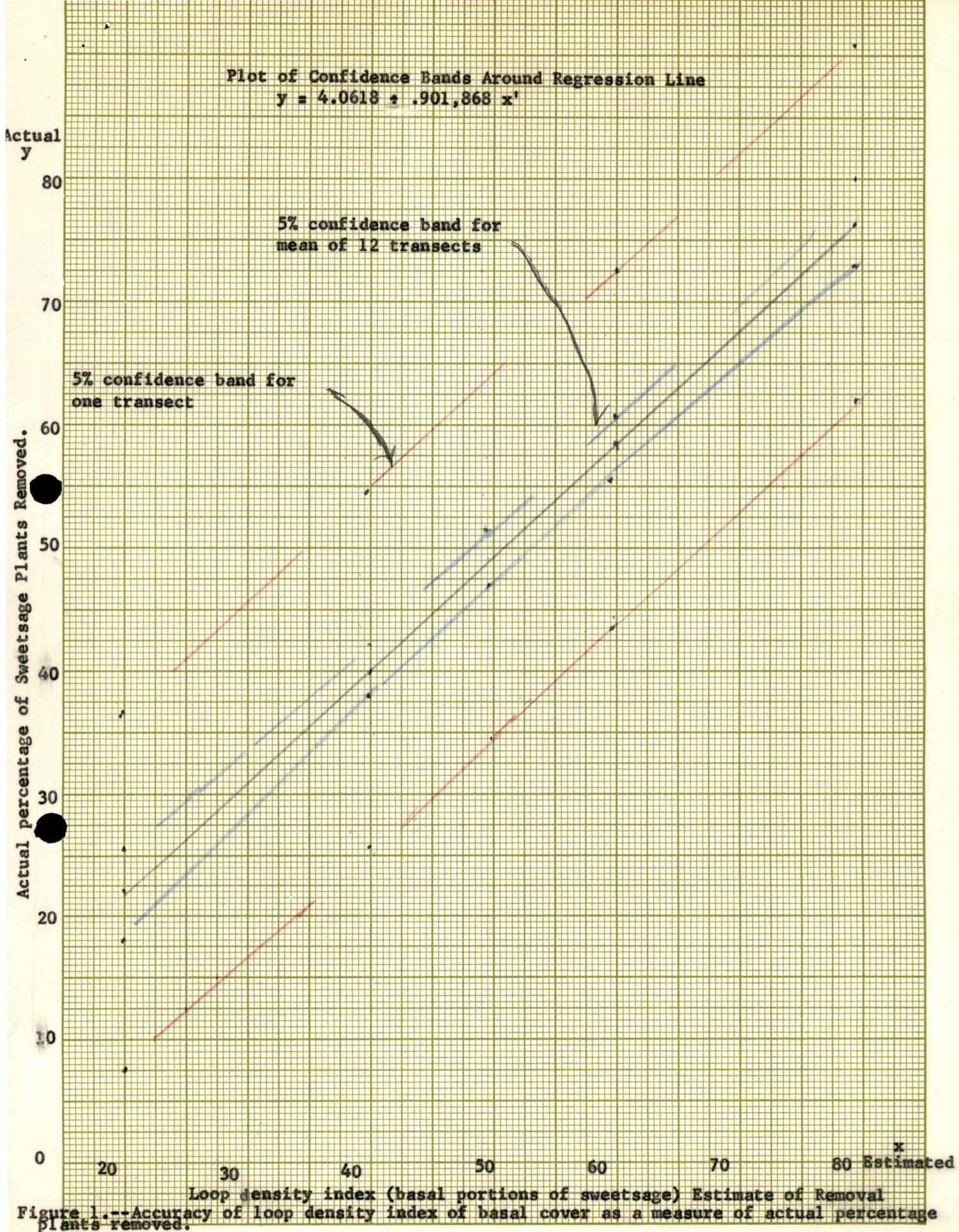

Figure 1.--Accuracy of loop density index of basal cover as a measure of actual percentage plants removed.

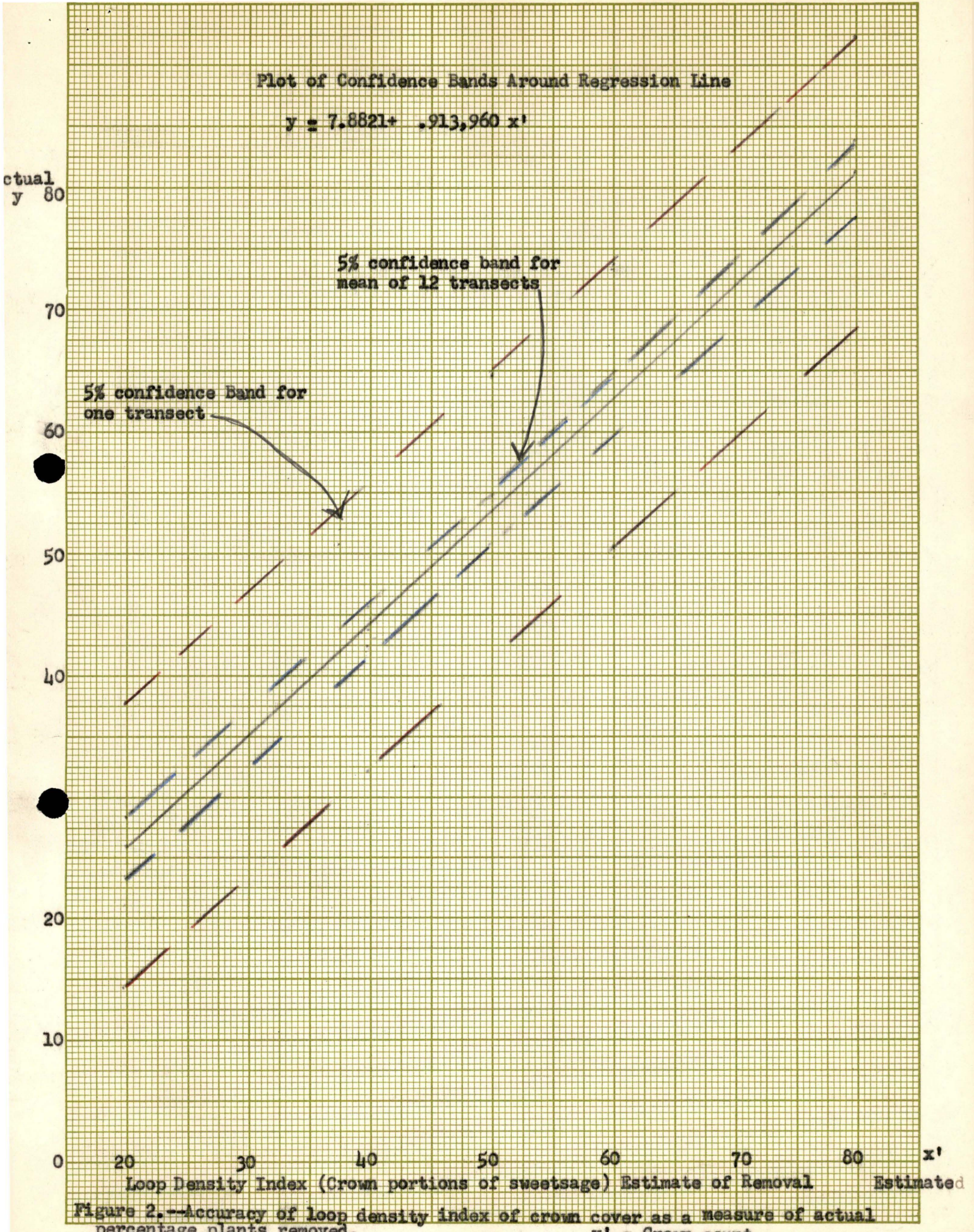

Figure 2.--Accuracy of loop density index of crown cover as a measure of actual percentage plants removed.

x' = Crown count

Table 2.--Sensitivity of loop method in reflecting changes in sweetsage population as removed in about 20 percent steps (average percentages from 12 transects)

Method	Stages of sweetsage removal					
	20	40	60	80	Left	Total
	(%)	(%)	(%)	(%)	(%)	(%)
Actual count	19.4	38.6	57.9	77.3	22.7	100.0
Basal index-density by loop	20.1	39.5	57.2	79.1	20.9	100.0
Crown index-density by loop	15.7	33.1	53.1	74.8	25.2	100.0

an adequate method for reflecting changes in density and composition. Known changes that have occurred in several range communities, especially with respect to density and composition have been determined by methods other than the loop method, largely by chart or list quadrats and by comparison of grazed and ungrazed range (enclosure). The question naturally arises, could similar changes have been picked up as well or better by the loop method? The answer is difficult, but one would assume, in the light of the favorable sensitivity tests, that the loop method would reflect similar change. Since it is basically similar, the loop method would unquestionably show the changes obtained by Huffaker and Holloway's ( ) "minute quadrat" method. Huffaker ( ) used this method successfully to document the return of native perennial bunchgrasses in California following the removal of Klamath weed (Hypericum perforatum L) by imported beetles.

Part of the answer is also forthcoming from comparison of the loop method with other methods as previously reported. Comparison of the loop method with the line intercept method which measures actual basal area showed a straight line relationship with very close correlation (r = .9719) between the two methods. Inasmuch as the index of basal density obtained by the line intercept method is very similar to that obtained from charted quadrats, it seems safe to conclude that the loop index relationship would also be linear and closely correlated. Furthermore, as reported by Bauer ( ), sampling by the line intercept transect gives decidedly more accurate percentages of coverage than quadrat sampling--probably because the transect has greater linear extent than the quadrat. Differences between men,

however, are less with the loop method (,). As pointed out by Clarke et al ( ), the intensity of sampling is an inverse function of the grass cover. Sparse covers require more sampling than those which are dense. In sparse vegetation the line intercept even with its 100-percent record of the vegetation on the line will likewise show extreme fluctuation in the compositionof the vegetation which may be overcome mainly by measuring more lines. The loop method does not make a 100-percent appraisal of the vegetation on a transect as in the case of the line transect or charted quadrat. Thus, its sensitivity probably increases with increase in the amount of vegetation present. Data obtained from the Flagtail allotment tests in Oregon 1/ show that where the basal index of density exceeds 20, the

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1/ Progress report on Flagtail Condition and Trend Methods Study. Prepared by Joseph F. Pechanec, February 19, 1951, in files of Pacific Northwest Forest and Range Experiment Station, 40 typed pages.

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loop method is fairly accurate, whereas in the densities below this accuracy decreases, especially with respect to composition. This is because the 100 observations taken at mechanical intervals may be erratic on an individual transect line and either miss or hit too much vegetation. This failing can be overcome through increasing the number of lines.

The low-density indices obtained on the Flagtail allotment for the open ponderosa pine type were among the lowest encountered during the course of the condition and trend study, as shown in table 3. Aside from the increased efficiency in sampling, the varying densities that were encountered led to the conclusion that it would be highly ad-

Table 3.--Summary of transect data on vegetation density indices obtained by loop method on important western range types in varying stages of condition

Location	Type	Rating of forage condition	Number of transects measured	Desirable forage species Av. density index	Total perennial vegetation Av. density index	Range in density index values
Oregon						
Malheur N. F.	Open ponderosa pine	Fair to good	15	5.9	8.3	2-20
	Sagebrush-bitterbrush	Poor	15	4.0	18.1	3-28
	Meadow	V.P. to excl.	15	32.5	73.1	-
Starkey Exp.Range	Pacific bunchgrass	Poor to fair	9	17.5	36.5 1/	20-66 1/
Montana						
Lewis & Clark	Mt. grassland	Excellent	4	56.4	68.0	63-73
	Mt. grassland	Good	2	32.3	72.0	71-74
	Mt. grassland	Fair	4	23.7	66.0 1/	57-82 1/
Vigilante Exp.Rg.	Mt. grassland	Fair to excl.	13	24.9	40.4 1/	26-58 1/
Colorado						
Manitou Exp.Rg.	Open ponderosa pine	Very poor	2	6.7	16.5	-
	Open ponderosa pine	Fair	2	13.8	28.0	-
	Ponderosa pine opening	Poor	2	22.0	48.5	-
	Ponderosa pine opening	Fair	2	19.2	45.0	-
Wyoming						
Bridger N. F.	Sagebrush-grass	Poor to fair	7	13.0	51.3	29-75
California						
Tahoe N. F.	Meadow, sagebrush-grass, open ponderosa pine, mt. grassland	Very poor to good	12	-	21.9 1/	1-79 1/
Arizona						
Coronado N. F.	Oak savannah	Poor to good	6	5.5	28.5	15-38
New Mexico						
Gila N. F.	Shortgrass openings in pinyon-juniper	Poor to fair	45	14.6	17.2	11-23

1/ Perennial grasses only.

vantageous in assuring greater accuracy to place the transects in groups or clusters on the site selected for sampling. Accordingly, in the specifications for the 3-Step Method ( ) it was suggested that a minimum of three transect lines be placed in clusters where the index of plant density is below 30; from 31 to 60 two transects, and above this or 61+ one transect per cluster.

As a means of attaining further sensitivity of the method, segregation of plant species into three groups, namely, desirable, intermediate, and undesirable was specified. In this respect the data presented in table 3 are of further interest. For example, note the measurements for Montana mountain grassland on the Lewis and Clark. The average total density index for all perennial vegetation tells little or nothing with respect to condition whereas there is a significant difference between condition classes in the abundance of desirable forage species. Similar findings are apparent for the Manitou data on open ponderosa pine and associated openings. In the latter, however, the total of desirable species for the poor condition range was slightly greater than the fair. But it was made up primarily of mountain muhly in poor vigor whereas the latter had in addition significant amounts of vigorous Arizona fescue which is an indicator species of better forage conditions. In addition to this difference the fair condition class had markedly less undesirable species and a higher proportion of intermediate species.

Composition is in most range types an important factor to follow in measuring the trend in forage condition. This is an ecologic axiom. An exception to this was the open ponderosa pine community encountered on the Malheur National Forest. Here the principal difference, aside from

vigor, between the condition classes was in the density of the key indicator species of top condition - pine grass (Calamagrostis rubescens) and elksedge (Carex geyeri). There was little difference apparent between condition classes with respect to composition. This appears to be borne out by data presented by Rummel ( ), especially with respect to the degree of abundance of elksedge.

2. Expression of herbage production.

In the collection of data on condition and trend on national forest range allotments, it is seldom possible to estimate or measure the amount of herbage produced because of lack of temporary panels to protect plots from utilization. Also, it is seldom convenient for the range technician to examine very many areas at the end of the growth season because of work loads and time schedules for other work. In spite of these administrative difficulties, it seemed desirable, if possible to do so, to see whether or not the loop method might be adopted to give an expression of herbage production. Accordingly, tests were conducted on the shortgrass range type at the Weld County Experimental Range in Colorado to determine the feasibility of modifying the loop method to secure an estimate of herbage production. The tests were largely exploratory and because of insufficient time, the method evolved was not tested intensively for its reliability. It was also concluded that if weight data were needed to meet special situations, that the weight-estimate method developed by Pechanec and Pickford ( ) would suffice in most instances. However, because of its possible interest to technicians adaptation of the loop method for estimating herbage production is described herewith.

In brief, the method considered was to evaluate each "hit" for each

major forage plant species in terms of pounds of herbage per acre. In the preliminary trial this was accomplished by measuring three 100-foot transect lines by the loop method. Along each transect line, at 20-foot intervals, a plot 1 x 2 feet in size was clipped and weighed. The average of the 5 plots on each transect line was then converted into pounds of herbage per acre. From these data it was possible to set up an index figure of herbage production for each "hit" by dividing the total herbage production on the three transect lines by the total number of "hits" on these lines. This was done for each major species and a base figure established that could be used for converting the "forage density index" into pounds per acre of herbage without additional plot clipping on subsequently measured transect lines. If the method is to be utilized, a greater number of transect lines (10 or more) than that utilized in this test should be measured with accompanying clipped plots in order to establish a more adequate base especially for the less abundant species. This was borne out by the Weld County test in that the base for the most abundant species, Blue grama, appeared adequate, whereas for the less abundant species, it was not too sound. This is indicated by the following data, wherein an estimate of herbage production was made by the loop method as compared to that indicated by clippings from plots located on the same site:

	Clipped plot actual weight index	Estimate of weight by loop method
	lbs. per acre	lbs. per acre
Blue grama	498.4	511.9
Needle and thread	226.6	106.5
Other grasses	80.7	57.6
Total	805.7	676.0

It will be noted that the greatest discrepancy is with needle and thread (Stipa comata), which made up about 8 percent of the composition, compared to 81 percent bluegrama (Bouteloua gracilis).

3. Applicability to Other Range Types

The modified frequency point or loop method was developed originally for grassland vegetation. As previously reported it was tested in a wide variety of range types in various stages of condition. Types included: the Pacific bunchgrass in Oregon, mountain grassland in Montana and California, mixed grama-oak savannah in Arizona, ponderosa pine-bunchgrass in Colorado, big sagebrush-grass in Wyoming and California, wet and dry meadows, bitterbrush and the annual type in California. Similar range types and condition situations were again encountered during the 1950 field season. In Utah especial effort was made to test the method in the aspen type.

Aspen.--The aspen type, including the openings, when in good condition, is characterized by lush, tall weeds or forbs up to 4 feet or more in height. It offers a special problem in sampling since the basal area of the forbs is small but the crown spread often forms a complete cover. Two condition situations, good and poor, were each sampled with three transect lines, each 50 feet long. Personal error between four men was not significant.

As shown by the data presented in table 4, percentage composition based on the basal readings does not give as good a picture of the floristic composition as that based on the crown cover. It was most inadequate on transect 6 where the density index was lowest. On the other hand, the basal readings presented an acceptable picture of other site factors whereas the crown readings did not. In the case of

Table 4.--Comparison of crown and basal readings by the loop method in an opening within the aspen type rated in good condition. Summary of three transects

Habitat factor	Transect 4		Transect 5		Transect 6	
	Crown	Basal	Crown	Basal	Crown	Basal
Composition (in percent)						
Brca	35.3	45.0	34.7	62.0	46.7	83.3
Agur	8.5	10.0	21.4	23.8	13.7	8.3
Osoc	17.0	10.0	21.4	9.5	11.2	8.3
Mertensia spp.	15.2	15.0	6.8	-	6.8	-
Thfe	2.6	-	-	-	-	-
Viam	1.6	5.0	5.9	-	5.8	-
Sambucus spp.	18.1	15.	7.4	-	-	-
Viguiera spp.	-	-	.5	-	10.4	-
Galium spp.	-	-	.3	4.7	-	-
Heracleum spp.	-	-	-	-	4.2	-
Aster spp.	-	-	-	-	1.0	-
Density index	100.0	20.0	98.0	21.0	97.0	12.0
Litter	0	70.0	1.0	67.0	2.0	64.0
Bare ground	0	9.0	1.0	10.0	1.0	20.0
Gopher activity	0	0	0	1.0	0	3.0
Rock	0	1.0	0	1.0	0	1.0

transect 4, with a complete crown cover, there is no information on litter, bare ground, etc.

In the aspen opening in poor condition, table 5, the best picture of composition is also obtained from the crown cover. This is also the case with the data obtained by the point analyzer method (not tested in the good condition site because equipment is not adapted to tall vegetation). The similarity of readings between the two methods for percentage composition as based on crown cover is striking. This is especially so since the point analyzer method as applied required 300 observation points as compared to 100 for the loop method. Furthermore, the two methods, although used on the same transect line, do not sample exactly the same population. The point analyzer samples only vegetation directly beneath the line whereas the loop method takes in plants as far out as 3/4 inch from the line.

The significance of these findings is that modification in the loop method is necessary for practical application in vegetation made up principally of forbs as is the case in the aspen type. A good picture of the composition could be obtained from the basal readings but it would require a prohibitive number of lines. In aspen vegetation, it is suggested that crown readings be utilized for composition and basal readings for density index, litter, bare ground and rock.

Reseeded Areas.--Where the area has been reseeded by broadcasting the seed no especial problems arise in sampling the area by the loop method. However, where the seed has been planted by a drill the plants will occur in rows which will be the width of the drill spacing. Since loop readings are also made at mechanical intervals it is possible to hit or to miss every drill row depending on the location of the transect stakes.

Table 5.--Comparison of readings obtained by point analyzer and loop methods on crown and basal portions of plants found within an opening in the aspen rated as in poor condition. Summary of one transect

Habitat factor	Point analyzer		Loop method	
	Crown	Basal	Crown	Basal
Composition (in percent)				
Popr	6.2	40.0	12.0	42.8
Brca	1.8	-	2.8	3.5
Agtr	-	-	.9	-
Taof	51.3	20.0	49.1	25.0
Ruoc	10.6	-	10.2	-
Chal	1.8	-	1.8	7.1
Vinul	13.3	20.0	6.5	-
Coli	3.5	20.0	1.8	14.2
Stja	2.7	-	-	-
Rume	2.7	-	2.8	-
Heho	.9	-	2.8	-
Podo	2.7	-	-	-
Asod	2.7	-	6.5	3.5
Viam	-	-	.9	-
Density index	37.7	1.7	54.0	14.0
Litter	20.3	34.3	16.0	32.0
Bare ground	41.0	62.3	29.0	53.0
Gopher activity	1.0	1.3	1.0	1.0
Rock	0	.3	0	0

Trials on drilled crested wheatgrass plantings in Utah indicated that this difficulty could be overcome by placing the transect tape at right angles to the drill rows. Then the 100 observations are made with a tape which has had the observation points randomized and marked with paint within each 1-foot segment. Classification of the data should be made from standards especially prepared for judging reseeded areas.

4. Measurement of litter--cover, depth, and weight.

On most range types in the West a record of the amount of litter is an especially valuable index of condition and trend in soil stability. Some exceptions to this are to be found in the desert shrub and grassland types of the Southwest, where litter does not accumulate in significant amounts even under pristine conditions because of its rapid oxidation by favorable temperature and moisture during the summer. Rapid destruction by termites is also an important factor according to Shreve ( ). Even in the more mesic climate of the Great Plains, Weaver ( ) found that litter may form complete coverage in the spaces between plants during a series of favorable growing seasons, and completely disappear during severe drought. In the higher and cooler regions typified by forest range types, climate is generally conducive to accumulation of litter.

The rate of accumulation of forage plant litter or mulch is influenced by the degree of utilization, the plant species, climate, and periodicity of fires.

In the measurement of litter for following trend, two things are important--coverage and depth. The amount of coverage is the more important criterion because litter 1/2-inch deep is or about as effective in its beneficial effects on infiltration rates as deeper amounts. The amount

of coverage may be measured quickly and fairly accurately by the loop method as previously considered. The procedure used in measuring litter-as is true also of bare soil, moss, rock, and erosion pavement, is less objective than the measurement of vegetation. This is so because the observer must estimate as to whether or not more or less than half the 3/4-diameter loop is dominated by one of these elements. Admittedly, there is danger of considerable bias in this somewhat subjective estimate. This might be reduced by estimating in tenths the coverage of the various elements observed inside the 3/4-diameter ring, but it would have made the method more complex as well as more tedious in recording and summarizing the data. Reduction of this bias can be obtained only by proper training and rigid adherence to the definition that litter is all dead vegetative matter regardless of origin.

Depth of litter is subject to fairly easy measurement. In the Flagtail allotment tests conducted in Oregon, litter in the open ponderosa pine-pinegrass-elksedge type was measured by means of a ruler at 10 spots, each spot being spaced at a 10-foot interval along each 100-foot transect lines. The personal error as determined from the data obtained by two men measuring the same 15 transect lines was not considered prohibitive.

At the San Joaquin Experimental Range, depth of litter has been recorded for several years on the 1-square foot plots utilized in following changes in vegetation in the California annual type. On the basis of these measurements litter classes have been devised as follows: absent, trace, light (less than 1/4-inch deep), and adequate (above 1/4-inch depth). Classification by this means was found to be more satisfactory and more quickly obtained than by weight, which requires extreme care to separate

the dead vegetative matter from mineral soil particles and also requires additional time and effort to determine the moisture content. In spite of these difficulties some range technicians prefer the weight method because it is an objective measurement. The additional time required to determine either depth or weight is probably not warranted for administrative use except possibly on allotments of especial interest.

5. Size of Loop.

During the field tests with the 3/4-inch diameter loop questions which arose concerning this specific size ring related mainly to its use as a measure of density and as to its efficiency in picking up rare species which might have important indicator value. These questions are considered herewith:

As a measure of density.--Density in the ecological sense, according to Hanson ( ), refers to the numbers of individual plants per unit area. However, "density" has long been recognized by most range technicians as referring to the percentage of ground surface covered by vegetation. In range reconnaissance "density" may be the crown spread of the leaves and stems as viewed vertically from above or in the case of spreading plants when bunched at an angle of 30 degrees from the vertical. It may be the basal area occupied at the ground surface or when clipped to a 1-inch height as in the case of charted quadrats. Density may include both crown and basal area, depending on the method of estimation or measurement involved and particularly if the vegetation is two-storied as in the case of shrubs and grasses.

Density will thus vary with the definition and methodology involved and in the exact sense "true density" is a misnomer. "Density index" is more meaningful and provides for further qualification such as "quadrat

density," "square foot density," or "range survey density." All these methods measure a real cover but the actual amount will vary greatly with the method. For example, 1 percent quadrat density may be equivalent to 10 percent range survey density.

"Density" in the sense of abundance is not as sound a criterion of change in vegetation as its areal definition because of the extreme variation in size and spread not only between species but also within the same species. For example, one plant of Veratrum can cover 10 square feet whereas hundreds and even thousands of individuals of cheatgrass would be required to cover the same space. Within the same species, such as cheatgrass, young stands with fewer individuals may cover as much actual ground surface as in dense old mature stands. In either case a change in numbers of cheatgrass would have little direct meaning in trend. The loss of a single Veratrum plant might have significance but if it were a small young plant its loss would not have the same import as the loss of a large well established plant. Other Major objections to the plant count methods for administrative use are that they are often extremely tedious and often the plant unit requires precise definition for many different species. Even with precise definition, errors in the field application may be great. ( ). Accordingly, for the purpose of following changes in condition of vegetation it seemed best to adopt the term "density" in the sense of area occupies.

The basal index of density for perennial grasses and weeds is the most sensitive to actual change in cover because it eliminates the errors which would arise in measurement of the crown spread as will occur with differences in size as arise from seasonal growth stage and current utilization. On the other hand, the crown spread of perennial shrubs,

excluding current seasonal twig growth, is the best measurement for a record of trend because the basal stem portion is subject to change in only one direction--increases size. It is for these reasons that the basal portions of grasses and the crowns of shrubs are selected for measurement in the 3-Step Method.

The loop method is also essentially a compromise between frequency and area-estimate methods. This was done deliberately in order to make the method as objective as possible. In other words, to make it so simple that the decision of the examiner is, insofar as possible, one of two alternates--as between black and white. The 3/4-inch-diameter loop can be regarded as a minute quadrat where plants are listed by frequency. However, it is so small that from a practical viewpoint it also approaches a mere point. This is especially true with large shrubs and types of high density. In other words, it is a "point of dimension" and may be classified as such as an index of density or area. Much the same thinking, but greatly exaggerated, lies behind the classification of much larger observation plots, such as employed in the Forest Survey ( ). In accordance with their definition of forest area, an acre of land is considered "forest" if tree canopy exceeds 10 percent even though the land may be under cultivation or pasture.

In sampling pastures, Heddle ( ) used frames 6 inches square, which were thrown out at random 100 times on the area being examined and the species encountered were simply listed. His remarks concerning his "specific frequency method" are of interest: "The smaller the frame and the larger the number of readings taken the more closely does this method approach the quantitative, but if this provision were carried to its logical conclusion, the size of the frame will be ultimately reduced to a

point, and the method merges into the point quadrat method." The method referred to is that of Levy and Madden ( ), who successfully employed it to measure the density of New Zealand grasslands. Another similarity of the loop method with its mechanically spaced observation points is to that reported by Tinney et al ( ) in Wisconsin wherein a string 36-inches long is stretched between two points and all plants whose crows are vertically beneath the line are counted and recorded. The method is reported as objective, reliable, and one of the best for showing rapid changes in floristic composition of pastures.

Size of loop as related to sampling efficiency.--As previously reported ( ), the size of the loop that was adopted finally evolved from attempts to tuilize small frames from 12 inches square down to 4 and 2 square inches in area. It was found that the error between men either in estimating area of plant cover or in counting the number of plants was prohibitive but the error decreased as the size of the frame was decreased. On the other extreme, a fine needle point required too many observations and was probably too tedious for administrative use. Accordingly, the 3/4-inch diameter ring was adopted as a compromise between a fine point and a small plot, wherein the needs for attaining a minimum error between men and for best satisfying sampling efficiency was best realized. It was recognized, however, that the sampling efficiency of the loop method and this would be true of most other methods, would vary mainly with the density of the vegetation. In other words, the more dense and uniform the vegetation, the fewer nember of observations would have to be recorded. This was borne out by the tests that were conducted in the various regions. The final specifications provided for this in that a minimum of three transect

lines be placed in a cluster where the index of plant density was below 30; from 31 to 60, two transects and above this or 61+ one transect cluster. Also, where rare but important key indicator species occur on the transect sampling plot (100 feet x 150 feet) but are not encountered in measurement of the line, these species are listed to record their presence at the time of the examination.

The various tests conducted with the loop method have been previously reported ( ). The results generally indicated that the method was well suited for administrative use and was adequate for measuring the major National Forest range types--especially grasslands, including meadows, sagebrush-grass, and open timber types. Results with aspen and reseeded areas have been considered previously. The basic method has been put to use by several other agencies including state game departments and state experiment stations. Only a few modifications have been made with respect to the ring diameter. One of these was originated by John Dibbern, of the U. S. Indian Service, on the Papago Indian Reservation where the range types are commonly desert shrub or desert grassland. These types are naturally sparse and very low in density according to Shreve ( ). Here the 3/4-inch diameter ring did not pick up an adequate sample of the vegetation unless a prohibitive number of lines were measured. This was overcome by utilizing a ring 2-1/2 inches in diameter, but the methodology otherwise remained the same.

6. Length of Line.

As provided for in the specifications of the 3-Step Method transects 100 feet in length were set up as a standard for most range types. However, it was also pointed out that in some situations, such as narrow meadow

stringers or rough terrain or dense shrub types, shorter length transects, 50 or even 25 feet long, would be preferred to the 100-foot length, because of greater ease in establishment and greater facility in relocation and re-measurement. Regardless of length of line, 100 observations are to be made with readings taken at 12-inch, 6-inch, or 3-inch intervals, whichever is appropriate, starting at the first 12, 6, or 3-inch spacing from the 0-end of the tape.

The basis for recommending the 100-foot length line was from the results of a study conducted in 1943 by the Southwestern Station on the effect of length of line on the efficiency of sampling. In a trial made in low-density grassland at the Santa Rita Experimental Range, lines varying in length from 10 to 50 feet were measured. Analysis and summarization of data are presented in table 6. It will be noted that the longer the line, the smaller the percent mean error, and the fewer lines required for the same level of sampling accuracy. Although the data were obtained by the line intercept method, which necessitates measurement of all vegetation occurring directly beneath the line, it was thought that the principle involved would also apply to the loop method. Furthermore, use of a line 100 feet in length on most range types helps reduce personal bias in selection of the spot to be sampled because there is less "freedom of choice" than would be the case with shorter length lines.

Table 6.--Comparison of the efficiency of different length lines for sampling the mixed grama range type. (Based on measurement of 20 lines of each length indicated by line intercept method.)

Length of line--in feet	10	20	30	40	50
Percent mean error	16.79	14.69	9.94	9.34	8.38
Number of lines necessary to reduce mean error to 10 percent or less	57	44	20	18	14

STEP TWO - CLASSIFICATION OF CONDITION AND ESTIMATION OF CURRENT TREND

Step Two requires the classification of forage and soil condition by means of score cards. Range condition and trend score cards were originally developed ( ) and tested in the Southwest. There they have been devised specifically for each of the important range types and these standards have been adopted for region-wide use by Administration for all national forests. Carefully obtained transect data and classification of condition with score cards based on sound criteria reduces the danger of faulty interpretation of field data and minimized personal bias. The numerical ratings obtained for vegetation and for soil stability avoid "stair-step" grades which must be assigned with purely adjective ratings and permit ready appraisal of trend in condition by comparison of initial ratings to those obtained in subsequent years. Numerical ratings also permit grading condition within a condition class and assignment without hesitancy as to adjective value in border-line cases where the condition is not clear cut as, for example, between good and fair.

As originally reported ( ), Steps One and Two of the 3-Step Method were quite independent of each other. Step Two did not utilize directly the data as obtained in Step One, but depended on data for density and composition obtained by the paced transect (also known as the step-point method). In addition to requiring an amount of time equal to that required in measurement of the permanently fixed transect by the loop method, the paced transect was found to have a prohibitive amount of bias. In the tests conducted on the Flagtail allotment Pechanec reported that inspection of the data obtained by the paced-transect method, the number of "hits" on perennials, litter, and bare ground, showed a wide and consistent

difference. The conclusion from the study was that the possibility for strong personal bias (plus error of sampling from never being able to relocate the same transect lines) makes the paced transect entirely unsuited for the detection of trends over a long period of time because of the wide variations between different observers.

Step Two as now specified ( ) utilizes directly the data obtained by the loop method from fixed transects for the classification of condition on the sites at the time of the examination. This procedure has led to greater uniformity between men. Close uniformity is well illustrated by the data presented in table 7, which were obtained by four men working independently on the same sites on the Flagstaff allotment in Montana. The data are also of interest in that the scores obtained for density were but slightly different between the excellent and fair condition. At the time the guides were prepared total plant density, which included the undesirable species, was used as a criterion of condition. Later experience and evidence subsequent to the Flagstaff tests[2/] indicated the need for adopting "forage density" which is comprised of only those species designated in the desirable and intermediate plant species groups. Forage density is that part of the plant density which the land manager is most desirous of increasing or maintaining through management. Increase or decrease in forage density over a period of years is consequently a reflection of the kind of management prevailing.

2/Establishment Report Trend in Range Condition, Flagstaff Management Unit, Lewis and Clark National Forest. Prepared by M. J. Reed, September 27, 1951. 12 typed pages. Also see RP-NRM SUPERVISION, Administrative Studies, Condition and Trend memorandum of March 2, 1951, prepared by Barry C. Park to Regional Forester, R-1. 14 typed pages.

Table 7.--Comparison of score card ratings on vegetation condition of four different men on five sites in mountain grassland type. Lewis and Clark National Forest, Montana, September 3-9. 1951

Site number	Man number	Score card rating: Density	Composition	Vigor	Total
1	1	10.0	14.0	9.0	33.0 Excl.
	2	10.0	14.0	8.7	32.7 Excl.
	3	10.0	14.0	9.0	33.0 Excl.
	4	10.0	14.0	9.0	33.0 Excl.
2	1	10.0	14.0	8.7	32.7 Excl.
	2	9.5	14.0	8.7	32.2 Excl.
	3	10.0	13.5	7.5	31.0 Excl.
	4	10.0	14.0	8.0	32.0 Excl.
3	1	10.0	11.5	5.7	27.2 Good
	2	8.2	10.5	8.0	26.7 Good
	3	9.5	11.0	6.5	27.0 Good
	4	9.5	12.5	7.0	29.0 Good
4	1	10.0	9.0	2.5	21.5 Fair
	2	9.5	10.0	4.0	23.5 Fair
	3	9.0	9.5	2.5	21.0 Fair
	4	9.5	9.0	3.0	21.5 Fair
5	1	9.5	10.0	3.0	22.5 Fair
	2	8.5	10.0	3.7	22.2 Fair
	3	9.5	10.0	3.7	23.2 Fair
	4	8.5	10.0	3.0	21.5 Fair

Incidentally, there was no suitable score card available for classifying condition in the Montana mountain grassland type as it occurred on the Lewis and Clark prior to the condition and trend study. This situation was met by careful study in the field, measuring by the loop method various condition situations found on the allotment, and by the application of knowledge gained elsewhere in this plant community. The job was accomplished during a week's time by the joint efforts of research and administrative personnel. It is recognized that criteria developed "on the spot" should be subject to additional recheck by research and administration whenever the opportunity and need for doing so occurs. Even though initial numerical and adjective ratings be assigned incorrectly in the light of subsequent information, the original basic field data obtained in Step One, if properly recorded, is always available for later reclassification if necessary.

In the Flagstaff study no attempt was made to prepare criteria for estimation of current trend in vegetation and soil. In such situations it is believed that trend can better be determined with the actual changes that occur on each of the transect clusters over the years.

Another item of interest presented in table 7 is the ratings shown for Man 4. These were based on information obtained by means of the paced transect, utilizing a cane with the 3/4 diameter ring attached. It was accomplished by taking 100 full paces, with an observation recorded at the end of each pace and in the same sites as the other men. Similarity of records obtained by Man 4 in comparison to the other men is apparent. These results indicated that the method was reliable for checking personal judgment that is entailed in the

selection of representative sites on the allotment for the establishment of permanent transect clusters.

Criteria presented in score card form for soil stability likewise, as in the case of vegetation, is a material aid in obtaining uniformity between men. This is illustrated by the data presented in table 8 for five different groups of men during a grazing-staff-men-ranger-training field class on the Coconino National Forest, Arizona, in September 1951. All groups were comparable as to the ratings obtained on vegetation with the widest discrepancy occurring where group No. 5 was involved. In this group the leader had not had intensive previous training in use of the loop method nor in plant identification. Possibly the latter factor was the more important because the ratings for erosion hazard are very similar on both Sites D and E. The erosion hazard rating, it will be recalled, is based on loop-method readings obtained from the transects.

Table 8.--Comparison of score card ratings of five groups[1] of men for vegetation and soil in three different range types on the Coconino National Forest, Arizona

Ratings	Site A[2]		Site B[2]		Site C[2]		Site D[2]		Site E[2]	
	Group No. 1	Group No. 2	Group No. 2	Group No. 3	Group No. 3	Group No. 4	Group No. 4	Group No. 5	Group No. 5	Group No. 1
Vegetation										
Forage density	3	3	11	12	9	10	4	6	8	12
Composition	12	12	7	6	13	12	5	5	12	12
Vigor	10	9	3	2	9	8	6	6	10	10
Total score	25	24	21	20	31	30	15	17	30	34
Adjective	Fair	Fair	Fair	Fair	Good	Good	Poor	Poor	Good	Good
Soil										
Erosion hazard	15	14	10	10	11	11	7	8	9	10
Current erosion	12	12	9	6	11	11	8	9	8	8
Aggregation	1	2	2	2	2	2	2	1	1	2
Compaction	4	4	2	1	3	4	3	3	3	2
Infiltration	4	4	3	1	4	4	3	3	3	3
Total score	36	36	26	20	31	32	23	24	24	25
Adjective	Good	Good	Fair	Fair	Good	Good	Fair	Fair	Fair	Fair

1/About six men in each group.

2/Site A = open ponderosa pine forest. Site B = pinyon-juniper type. Sites C, D, E = ponderosa pine bunchgrass parks.

STEP THREE - THE PHOTOGRAPHIC RECORD

Step Three consists of two key photographs, a general type photo and a closeup of a 3'x3' plot taken obliquely from the same point as the general photo. The two together form a visual record, in part at least, of the elements observed and measured in Step One.

No tests were made and adoptions of this part of the method was based on experience with the photo-transect method in the Intermountain Region where it was found the general photo and the oblique closeup to be the most suitable for showing changes in condition. However, repeat photographs can be deceiving as to magnitude of indicated change. For example, a photograph taken before the onset of plant growth may show a considerable difference if repeated even in the same year but later in the season. Also there is a wide difference in the appearance of vegetation before and after grazing use. (See figures.....(453919 and 454040). It is for this reason that photographs should be repeated at about the same time in the season as the original. Another pitfall in repeat photographs is in their use for efficiently showing soil loss. Even if repeated 10 years later a photo might show the gulley cutting as having healed over and yet sheet erosion might still be continuing apace. Repeat photos, although having many admirable advantages, do have distinct limitations.

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